

AD-A139 635

FIVE TIMES COMPRESSION OF MODE-LOCKED ARGON ION LASER
PULSES(U) CALIFORNIA UNIV SAN DIEGO LA JOLLA DEPT OF
CHEMISTRY C G DUPUY ET AL. MAR 84 TR-17

1/1

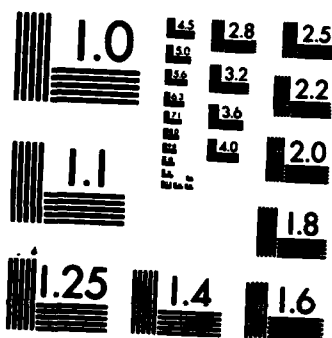
UNCLASSIFIED

N00014-78-C-0325

F/G 20/5

NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

12

OFFICE OF NAVAL RESEARCH

Contract N00014-78 C-0325

TECHNICAL REPORT NO. 17

AD A139635

FIVE TIMES COMPRESSION OF
MODE-LOCKED ARGON ION LASER PULSES

BY

CHARLES G. DUPUY AND PHILIPPE BADO*
Department of Chemistry
University of California, San Diego
La Jolla, CA 92093

Prepared for Publication
in
Optics Communications

DTIC
ELECTE
S APR 3 1984 D
K A

Reproduction in whole or in part is permitted for any purposes of the United States Government.

This document has been approved for public release and sale; its distribution is unlimited.

* Present address: Laboratory for Laser Energetics, University of Rochester,
250 East River Road, Rochester, New York 14623

DTIC FILE COPY

84 04 02 064

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 17	2. GOVT ACCESSION NO. AD-A139635	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) FIVE TIMES COMPRESSION OF MODE-LOCKED ARGON ION LASER PULSES		5. TYPE OF REPORT & PERIOD COVERED Technical
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Charles G. Dupuy and Philippe Bado		8. CONTRACT OR GRANT NUMBER(s) ONR-N00014-78 C-0325
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Chemistry University of California, San Diego La Jolla, CA 92093		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Arlington, VA 22217		12. REPORT DATE March 1984
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES 4
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) This document has been approved for public release and sale; its distribution is unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Submitted to Optics Communications, February 1984		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) fiber optic pulse compression		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The authors We report a five times compression of the 110 ps, 11 nJ pulses from a mode- locked argon ion laser. The pulses are frequency broadened and chirped during passage through a polarization conserving single-mode optical fiber 90 m in length, then compressed by a diffraction grating stage to 22 ps.		

Five Times Compression of Mode-Locked Argon Ion Laser Pulses

*Charles G. Dupuy and Philippe Bado**

Department of Chemistry B-014
University of California at San Diego
La Jolla, California 92093

ABSTRACT

We report a five times compression of the 110 ps , 11 nJ pulses from a mode-locked argon ion laser. The pulses are frequency broadened and chirped during passage through a polarization conserving single-mode optical fiber 90 m in length, then compressed by a diffraction grating stage to 22 ps.

submitted to: Optics Communications, February 1984

Accession For	
DTIC GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
unannounced	<input type="checkbox"/>
Distribution	
By	
Distribution/	
Availability Codes	
Avail and/or	Special
inst	
A-1	



* Present address: Laboratory for Laser Energetics, University of Rochester, 250 East River Road, Rochester, New York 14623

Five Times Compression of Mode-Locked Argon Ion Laser Pulses

Charles G. Dupuy and Philippe Bado*

Department of Chemistry B-014
University of California at San Diego
La Jolla, California 92093

INTRODUCTION

For short input pulses, such as the ones generated by mode-locked dye lasers, it is possible with a short length of optical fiber to take full advantage of the combined features of self-phase modulation and group velocity dispersion to generate linearly chirped pulses, as shown recently by Grischkowsky, et al.¹⁻⁴ and Shank et al.⁵ Pulse compressions of more than an order of magnitude have been achieved by sending this frequency broadened and chirped output of the fiber onto a dispersive diffraction grating delay line.³ We demonstrate that the same technique can be used to compress the longer temporal pulses from a mode-locked argon ion laser (with easy extension to frequency doubled, cw mode-locked Nd/YAG pulses) despite the less favorable conditions of narrower initial bandwidth and lower peak power.

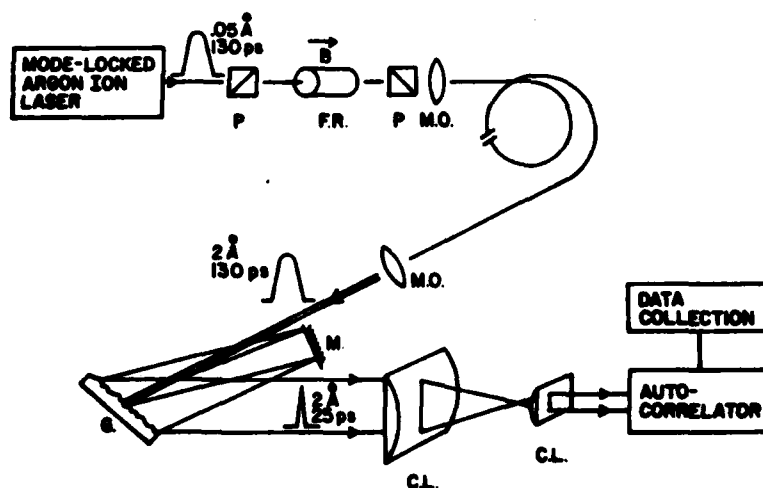


FIG. 1 Schematic diagram of the experimental apparatus: P = polarizer, F.R. = Faraday rotator, \vec{B} = magnetic field, M.O. = microscope objective, G = grating, and C.L. = cylindrical lens

The experimental apparatus is shown schematically in Fig. 1. The laser source is a Spectra Physics model 171 mode-locked argon ion laser operated at 5145 Å. Typical working conditions were 850 mW output power at 80 MHz repetition rate. The pulse width (FWHM) was 110 ps, as monitored by a fast photodiode (Spectra Physics, model 403B) and a sampling oscilloscope (Tektronix model 7603, 7S12 sampling head model S-6).

The optical fiber used in these experiments was provided by Dr. Stolen of Bell Laboratories. It has a 2.8 μm pure silica core with an elliptical borosilicate cladding and an index difference of 0.0089. The characteristic properties of this fiber have been described in detail by Ramaswamy, Stolen et al.⁶ The light was coupled in and out of the 2.8 μm core of the fiber by

* Present address: Laboratory for Laser Energetics, University of Rochester, 250 East River Road, Rochester, New York 14623

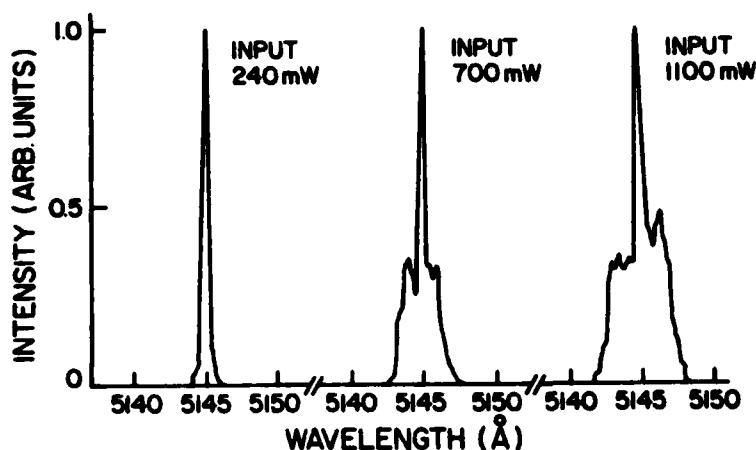


FIG. 2 Frequency spectra of the pulses at the output of the fiber for three different input powers. The monochromator resolution-limited peak due to non-broadened light transmitted through the cladding was included for comparison.

a 10x or 20x microscope objective. By careful alignment of the polarization along one of the principal axis of the cladding, it was possible to obtain a 90 to 1 conservation of polarization and a power throughput of 25%. Due to the small core diameter the alignment is very sensitive to vibrations, so values of 10% power throughput and 12:1 ratio of polarization were more typical operating conditions. The fiber length in these experiments was 90 m and the loss at 5145 Å is 40 dB/km.

A Faraday rotator consisting of two polarizers, a fixed field magnet of 2.3 kG and a 1x10 cm Terbium doped glass rod (Hoya Optical FR-5) was used to decouple the laser cavity from back scattered Rayleigh light and the reflections from the microscope objectives and fiber ends. Even with the Faraday rotator, feedback from the fiber considerably degraded the mode-locking when the argon laser was operated above 850 mW.

The pulse widths were measured with a fast diode or with a background free autocorrelator, in which a 2 mm Lithium Formate crystal (Quantum Technology) was used to frequency double the 5145 Å light. The signal from the photomultiplier was recorded by a computer interfaced picoammeter (Keithely, model 416). The bandwidth of the input argon laser pulses was measured with a confocal air-spaced Fabry-Perot etalon with a free spectral range of 1 cm^{-1} (Quanta-Ray, model FPA-1). At the output of the fiber the bandwidth of the frequency broadened pulses was measured with the Fabry-Perot etalon or a monochromator (Spex, model 1870) operated in first order with a resolution of $\sim 0.5 \text{ Å}$.

The initial argon pulses were close to transform limited with a bandwidth of $\sim 0.05 \text{ Å}$ and a pulse width of $\sim 110 \text{ ps}$. Figure 2 shows the bandwidth recorded at the output of the fiber, before the grating, for three different argon ion laser input powers. At 240 mW input power the spectrum was still resolution-limited on the monochromator, even though the bandwidth was already considerable broader than the 1 cm^{-1} (0.1 Å) free spectral range of the Fabry-Perot etalon. At 700 mW input power the bandwidth was $\sim 2.5 \text{ Å}$. Bandwidth of up to 4 Å was achieved with 1.1 W input power. The resolution-limited peak due to the non-broadened argon light transmitted through the cladding was included for calibration in the spectra of Fig. 2. In the pulse compression experiment it was removed by mode strippers and apertures.

Since the generated bandwidth is strongly dependent on the coupling efficiency, under typical operating conditions, the 850 mW input power yielded $\sim 2.5 \text{ Å}$, which represents a ~ 50 fold increase over the initial bandwidth. The autocorrelation of the pulses at the output of the fiber, before the grating compressor, was essentially the same as that of the input pulses, showing that group velocity dispersion effect is small.

The frequency broadened pulses from the optical fiber were compressed with a dispersive delay line using a single grating (PTR, holographic, 2400 line/mm) in a double pass

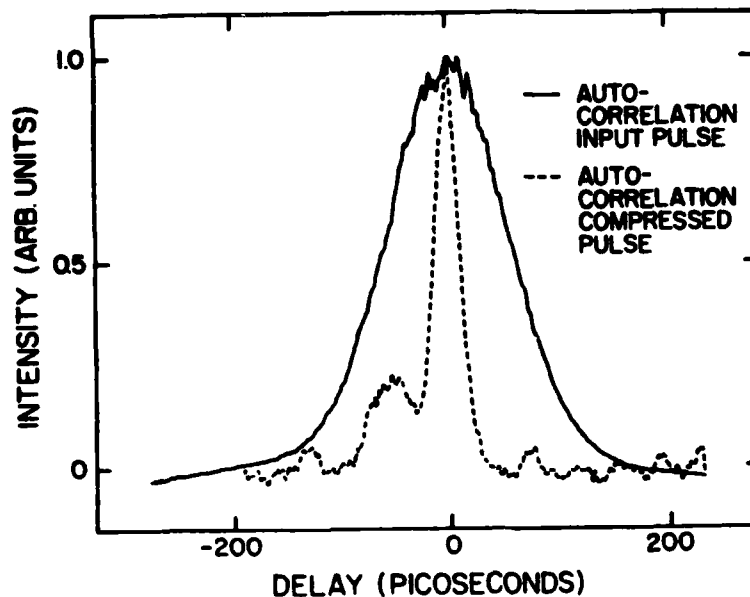


FIG. 3 Autocorrelation traces of the input and compressed pulses.

configuration as shown in Fig. 1. The grating was used at near grazing angle to obtain high dispersion⁷ and had an efficiency of ~45% per pass. As pointed out to us later by R. Stolen, the design of our grating compressor was not optimal. By using a mirror to reflect the light back on the single grating, instead of using a right angle prism as did Grischkowsky et al.,³ we did not obtain a collimated output beam, and could achieve linear dispersion only in a localized spatial region following the second pass on the diffraction grating.

The shortest pulses were obtained with a grating-grating distance of $1.5 \pm .1$ m, which is close to the value of 2 m calculated for the 15 degree incident angle.⁸ Figure 3 shows the autocorrelation traces of the input and of the compressed pulses. Due to poor alignment of the autocorrelator, the autocorrelation trace of the compressed pulse was asymmetric. For other operating conditions secondary peaks symmetrically centered with respect to the main peak have been recorded. Such secondary peaks are expected for pulses which are not linearly chirped over the full bandwidth, as is likely to be the case here due to the narrow initial bandwidth, low peak power and moderate fiber length.⁹

In order to compress the 110 ps pulses, the grating stage must introduce a ~3 cm path length difference between the leading blue edge and the trailing red edge. After compression by the grating stage the beam was a band ~2 mm high and ~30 mm wide. A cylindrical telescope was used to reduce the asymmetry in the beam to 2 x 5 mm. An alternative way to reduce the astigmatism is to greatly increase the beam diameter before the grating stage, then reduce it with spherical lenses. Clearly a scheme for linear compression without beam shape deformation is desirable. A possible candidate might be the near resonant absorption in metal vapor used by Nakatsuka and Grischkowsky to compress dye laser pulses.¹⁰

In summary we have demonstrated the use of optical fiber and a diffraction grating stage to compress by a factor of five the 110 ps, 5145 Å pulses from a mode-locked argon ion laser. Given the large bandwidth generated in the optical fiber an additional factor of 10 in compression is theoretically possible. A lower loss single mode fiber would be desirable to take full advantage of this technique.

Acknowledgement

We thank the National Science Foundation, Chemistry and the Office of Naval Research, Chemistry for the financial support which has made this work possible, and the Swiss National Foundation for fellowship support for P. Bado.

The authors would like to thank R. Stolen (Bell Laboratories) for his advice, encouragement and critique of our work, as well as for the loan of the optical fiber. We also thank R. Byer and T. Kane (Stanford University) for the loan of the Terbium glass rod and R. Boggy (Spectra Physics) for the loan of the autocorrelation crystal. We are also indebted to K. R. Wilson for the use of his laboratories.

References

1. Hiroki Nakatsuka, D. Grischkowsky, and A. C. Balant, "Nonlinear picosecond-pulse propagation through optical fibers positive group velocity dispersion," *Phys. Rev. Lett.*, vol. 47, pp. 910-913 (1981).
2. D. Grischkowsky and A. C. Balant, "Optical pulse compression based on enhanced frequency chirping," *Appl. Phys. Lett.*, vol. 41, pp. 1-3 (1982).
3. B. Nikolaus and D. Grischkowsky, "12x pulse compression using optical fibers," *Appl. Phys. Lett.*, vol. 42, pp. 1-2 (1983).
4. B. Nikolaus and D. Grischkowsky, "90-fs tunable optical pulses obtained by two-stage pulse compression," *Appl. Phys. Lett.*, vol. 43, pp. 228-230 (1983).
5. C. V. Shank, R. L. Fork, R. Yen, R. H. Stolen, and W. J. Tomlinson, "Compression of femtosecond optical pulses," *Appl. Phys. Lett.*, vol. 40, pp. 761-763 (1982).
6. V. Ramaswamy, R. H. Stolen, M. D. Divino, and W. Pleibel, "Birefringence in elliptically clad borosilicate single-mode fibers," *Appl. Opt.*, vol. 18, pp. 4080-4086 (1979).
7. J. D. McMullen, "Analysis of compression of frequency chirped optical pulses by a strongly dispersive grating pair," *Appl. Opt.*, vol. 18, pp. 737-741 (1979).
8. E. B. Treacy, "Optical pulse compression with diffraction gratings," *IEEE J. Quantum Electron.*, vol. QE-5, pp. 454-458 (1969).
9. R. H. Stolen and Chinlon Lin, "Self-phase-modulation in silica optical fibers," *Phys. Rev. A*, vol. 17, pp. 1448-1453 (1978).
10. Hiroki Nakatsuka and D. Grischkowsky, "Recompression of optical pulses broadened by passage through optical fibers," *Opt. Lett.*, vol. 6, pp. 13-15 (1981).

TECHNICAL REPORT DISTRIBUTION LIST, GEN

	<u>No. Copies</u>		<u>No. Copies</u>
Office of Naval Research ATTN: Code 413 800 North Quincy Street Arlington, Virginia 22217	2	Naval Ocean Systems Center ATTN: Mr. Joe McCartney San Diego, California 92152	1
ONR Pasadena Detachment ATTN: Dr. R. J. Marcus 1030 East Green Street Pasadena, California 91106	1	Naval Weapons Center ATTN: Dr. A. B. Amster, Chemistry Division China Lake, California 93555	1
Commander, Naval Air Systems Command ATTN: Code 310C (H. Rosenwasser) Department of the Navy Washington, D. C. 20360	1	Naval Civil Engineering Laboratory ATTN: Dr. R. W. Drisko Port Hueneme, California 93401	1
Defense Technical Information Center Building 5, Cameron Station Alexandria, Virginia 22314	12	Dean William Tolles Naval Postgraduate School Monterey, California 93940	1
Dr. Fred Saalfeld Chemistry Division, Code 6100 Naval Research Laboratory Washington, D. C. 20375	1	Scientific Advisor Commandant of the Marine Corps (Code RD-1) Washington, D. C. 20380	1
U.S. Army Research Office ATTN: CRD-AA-IP P.O. Box 12211 Research Triangle Park, N.C. 27709	1	Naval Ship Research and Development Center ATTN: Dr. G. Bosmajian, Applied Chemistry Division Annapolis, Maryland 21401	1
Mr. Vincent Schaper DTNSRDC Code 2803 Annapolis, Maryland 21402	.	Mr. John Boyle Materials Branch Naval Ship Engineering Center Philadelphia, Pennsylvania 19112	1
Naval Ocean Systems Center ATTN: Dr. S. Yamamoto Marine Sciences Division San Diego, California 91232		Mr. A. M. Anzalone Administrative Librarian PLASTEC/ARRADCOM Bldg. 3401 Dover, New Jersey 07801	1

TECHNICAL REPORT DISTRIBUTION LIST, 051B

	<u>No. Copies</u>		<u>No. Copies</u>
Professor K. Wilson Dept. of Chemistry, B014 University of California, San Diego La Jolla, California 92093	1	Dr. J. Telford University of Nevada System Desert Research Institute Lab of Atmospheric Physics Reno, Nevada 89507	1
Professor C. A. Angell Department of Chemistry Purdue University West Lafayette, Indiana 47907	1	Dr. B. Vonnegut State University of New York Earth Science Building 1400 Washington Avenue Albany, New York 12203	1
Professor P. Meijer Department of Physics Catholic University of America Washington, D. C. 20064	1	Dr. Hank Loos Laguna Research Laboratory 21421 Stans Lane Laguna Beach, California 92651	1
Dr. S. Greer Chemistry Department University of Maryland College Park, Maryland 20742	1	Dr. John Latham University of Manchester Institute of Science & Technology P.O. Box 88 Manchester, England M601QD	1
Professor P. Delahay New York University 100 Washington Square East New York, New York 10003	1		
Dr. T. Ashworth Department of Physics South Dakota School of Mines & Technology Rapid City, South Dakota 57701	1		
Dr. G. Gross New Mexico Institute of Mining & Technology Socorro, New Mexico 87801	1		
Dr. J. Kassner Space Science Research Center University of Missouri - Rolla Rolla, Missouri 65401	1		

END

FILMED

5-84

DTIC